HI-4456

Isotropic Electric Field Probe
User's Manual

Declaration of Conformity

We,
HOLADAY INDUSTRIES, INC.
14825 MARTIN DRIVE
EDEN PRAIRIE, MN 55344
USA

declare in our own responsibility, that the HOLADAY product described in this instruction manual is in compliance with: EN EMC Directive 89/336/EEC, EN50082-1, EN55011

President
HOLADAY INDUSTRIES, INC.

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HI–4456 Isotropic Electric Field Probe

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---	Release	8/97
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Limited Warranty

Holaday Industries, Inc. warrants each model HI—4456 Isotropic Electric Field Probe to be free from defects in material and workmanship for a period of one year from the date of shipment to the purchaser. This warranty extends to the original purchaser only, and does not apply to the batteries or to any products or parts subject to misuse, neglect, accident, unauthorized service or abnormal conditions of operation.

In the event an instrument covered by this warranty fails, Holaday Industries, Inc. will, without charge, repair and recalibrate the instrument if returned to their factory within one year of the original purchase-provided that Holaday Industries' examination discloses, to its satisfaction, that the product is defective. Holaday Industries, Inc., may, at its option, replace the product in lieu of repair. If the defect was caused by misuse, neglect, accident, unauthorized service or abnormal conditions of operation, repairs will be billed at a nominal cost. In such cases, an estimate will be provided before work is started, if requested by the purchaser.

For warranty service, contact Holaday Industries, Inc. Provide the serial number of the instrument and complete details regarding the failure mode. You will then be given either service information or shipping instructions. Return the instrument to the factory, transportation prepaid. Repairs will be made at the factory and the instrument will be returned to you, transportation prepaid. Holaday Industries, Inc., assumes no responsibility for loss of, or damage to, products in transit.

Warning!

EXTREME CAUTION IS ADVISED WHEN WORKING IN ENVIRONMENTS WHERE HIGH-INTENSITY ELECTROMAGNETIC FIELDS MAY EXIST AND WHERE CONTACT WITH HIGH VOLTAGE OR HIGH CURRENT CIRCUITS OR APPARATUS IS POSSIBLE. ACCIDENTAL CONTACT WITH OBJECTS OR CIRCUITS OPERATING AT HIGH VOLTAGES OR HIGH CURRENTS CAN BE LETHAL! HOLADAY INDUSTRIES, INC. ASSUMES NO LIABILITY FOR ANY DAMAGES OR PERSONAL INJURY WHICH MAY RESULT FROM

1.0 DESCRIPTION

Introduction

The HI-4456 RF Electric Field probe is a broadband isotropic sensor suitable for a wide range of RF/microwave measurements. While the HI-4456 is suited for many types of measurements within its frequency range, it is primarily designed for measuring pulsed fields such as are found in radar applications. The thermal sensor elements respond accurately to a wide range of signal waveforms, providing a true RMS representation of the field waveform.

Applications include: health and safety monitoring, radar transmitting antennas, and measuring any type of RF pulsed radiation. The HI-4456 probe is optically isolated to minimize field perturbation during measurements.

The HI-4456 probe assembly consists of a spherical casing, containing the sensor, which is mounted on one end of a shaft; the other end of the shaft is attached to an extrusion which houses the electronics (Figure 1—1). The sensor and electronics housing operate - and are calibrated - as a unit.

The HI-4456 sensor consists of three mutually orthogonal (perpendicular) electric field sensors. The electric field components in each of these directions are summed as vectors and the resultant field value (magnitude) transmitted via the fiber optic cable to the receiver (HI-4416 System Readout or HI-4413G RS-232 Computer Interface).

The frequency response of the HI-4456 extends from 300 MHz to 18 GHz. Extended frequency calibration points are available up to 40 GHz.. The dynamic range

of the probe extends from 0.3 mW/cm^2 to 265 mW/cm^2.

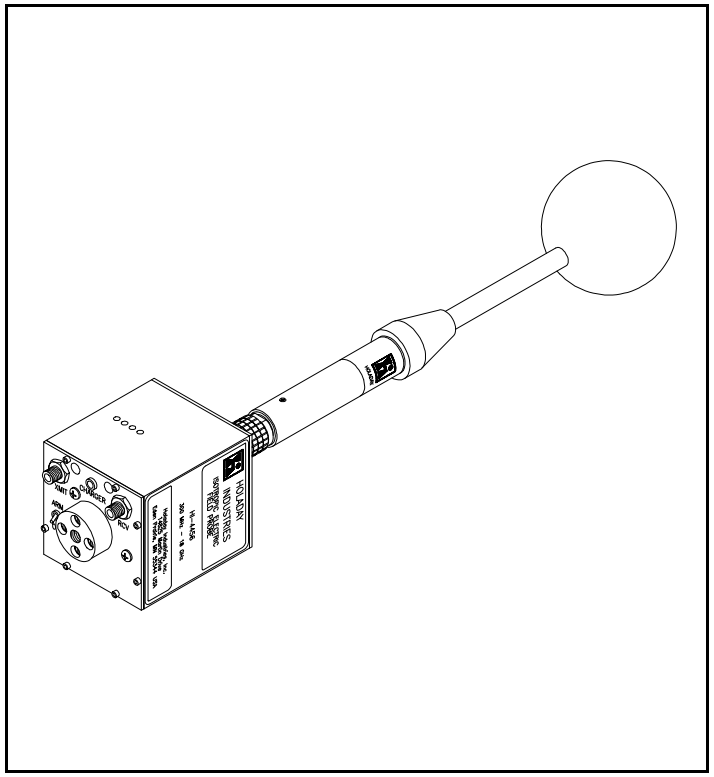

Figure 1—1
HI—4456 Probe

2.0 HI—4456 SPECIFICATIONS

Dynamic Range:	0.3 to 265 mW/cm^2
Ranges:	100, 300, 1 000 Volts/meter full scale
Frequency Response:	300 MHz to 1 GHz +0, -3 dB 1 GHz to 18 GHz ± 1.5 dB 18 GHz to 40 GHz +0, -6dB
Linearity:	± 0.5 dB full scale (F.S.): ± 2 least significant bits (LSBs) of A/D converter
Isotropicity:	300 MHZ to 18 GHz ± 1.2 dB 18 GHz to 40 GHz ± 2 dB
Peak Overload:	30 W/cm^2
Pulse Energy Density Overload:	150 W-μsec/cm^2
Environmental:	
Operating Temperature:	10 °C to 40 °C (50 °F to 104 °F)
Humidity:	5% to 95% relative humidity, non-condensing
Fiber Optic Cable Connectors:	Standard FSMA
Battery:	3.6 VDC, 1400 mA-h rechargeable Nickel-Cadmium (NiCd)

Battery Charger: 115/230 VAC, approximately 1 hour

Battery Life: 17 Hours continuous (full charge)

Probe Mount: ¼ — 20 UNC tapped hole (internal thread) in base of probe

Size:
Length (including electronics housing): 419 mm (16.5 in)
Probe diameter: 76 mm (3.0 in)

Weight: 0.54 Kg (19 oz.)

Optional Equipment: See Table 5—2

3.0 ACCEPTANCE AND CONTROLS

Introduction

This section contains information on: unpacking and acceptance of the HI—4456; probe controls; probe connectors; the battery, and the battery charger.

Unpacking and Acceptance

Step 1. Upon delivery of your order, inspect the shipping container(s) for evidence of damage. Record any damage on the delivery receipt before signing. In case of concealed damage or loss, retain the packing materials for inspection by the carrier.

Step 2. Remove the probe from its shipping containers. Save the boxes and any protective packing materials for future use.

Step 3. Check all materials against the packing list to verify that the equipment received matches that which was ordered. If you find any discrepancies, note them and call Holaday Customer Service for further instructions.

Be sure that you are satisfied with the contents of your order and the condition of your equipment before installing the probe.

Probe

A switch, two fiber optic connectors and a battery charger connector are mounted on the HI—4456 electronics housing (Figure 3—1).

XMIT/RCV The fiber optic cable assembly from the receiver is attached to the probe via two

connectors. The cables are color-coded-white for XMIT, yellow for RCV. Identically-colored dots are located on the electronics housing adjacent to these connectors. Be sure that each cable is attached to the proper probe connector.

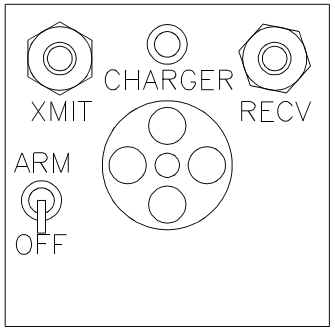

Figure 3–1
Switch and Connectors

When the fiber optic cables are not attached, always cover the probe connectors with the protective plastic covers supplied with the unit, or with similar material. This prevents dirt or other contaminants from entering the connector and causing communication problems.

ARM/OFF The ARM/OFF switch activates and deactivates the probe. In the ARM position, the probe is powered by its internal 3.6 VDC NiCd battery: in the OFF position, the probe is inactive. To prolong battery life, set the ARM/OFF switch to OFF at the end of a test sequence or when the probe is not in use.

CHARGER A standard fast charger is supplied with the HI—4456. When charging is complete, the fast charger acts as a trickle charger. The battery can be left on this maintenance mode indefinitely and it's performance will not degrade.

Battery

The NiCd battery provides up to 17 hours of probe operation when fully charged.

4.0 BATTERY CHARGING

Introduction

Each HI—4456 probe contains a rechargeable nickel-cadmium (NiCd) battery. A fully-charged battery (nominal output voltage of 3.6 VDC) provides up to 17 hours of continuous operation.

NOTE

Holaday Industries, Inc., charges the internal NiCd battery of the HI—4456 at the factory in order to calibrate the probe prior to shipment. While every effort is made to ensure that your probe arrives ready to use, we cannot guarantee that this will be the case. Always check the condition of the probe's battery prior to making any measurements. To check probe battery voltage, refer to the operation of the BAT keypad in Section 8.0 of the HI—4416 User's Manual.

Charging Procedure

Step 1. Plug the charger into a suitable AC source.

Step 2. Set the probe switch to OFF. Insert the plug on the charger cable into the probe's CHARGER jack.

Step 3. The battery is now charging. This may take approximately 1 hour, depending on how deeply the batteries are discharged. When charging is complete, the charger automatically goes into a trickle charge and will continue to do so until the probe is disconnected.

Battery Tips

NiCd batteries have several characteristics that can affect both their performance and operating life. The following tips advise you how to take advantage of these characteristics to get the most out of your probe's battery.

Although NiCd batteries are rated for operation in temperatures from -20 °C to +65 °C (-4 °F to +140 °F), operating the probe in extreme temperatures will reduce operating time significantly. The optimum operating temperature range for these batteries is +20 °C to +30 °C (+68 °F to +86 °F).

The battery in the HI—4456 probe does not require periodic "deep discharges" to reverse the capacity-depleting "memory effect" caused by repeated shallow discharges; however, undercharging can reduce battery capacity. Therefore, after the charging procedure is complete, be sure that the battery is fully charged before resuming field operation.

If the battery exhibits low terminal voltage during charging, or if it appears unable to acquire or maintain an appreciable charge, individual cells in the battery may be shorted or damaged. If, for any reason, your battery needs replacement, contact Holaday Customer Service for assistance.

5.0 MAINTENANCE

Introduction
This section explains which maintenance tasks can be performed by the user. It also provides information regarding replacement and optional parts. If you have any questions concerning probe maintenance, consult Holaday Customer Service.

Maintenance Recommendations
Maintenance of the HI—4456 probe is limited to external components such as cables or connectors.

Any calibration or maintenance task which requires probe disassembly should be performed at the factory. Check with Holaday Customer Service (952-934-4920) before opening the unit to avoid problems with your probe's warranty.

NOTE
Opening the probe enclosure may void your warranty. If your system is still under warranty, contact Holaday Customer Service before performing any maintenance inside the probe.

Upgrade Policies
Periodically, probes are upgraded to enhance functionality. These upgrades are commonly announced through Holaday Engineering Bulletins.

Return Procedures
To return a probe to Holaday, use the following procedures:

Step 1. Briefly describe the problem in writing. Give

details regarding the observed symptom(s), and whether the problem is constant or intermittent in nature. If you have talked previously to Holaday Customer Service about the problem, provide the date(s), the name of the service representative you spoke with, and the nature of the conversation. Include the serial number of the item being returned.

Step 2. The sensor and electronics housing are engineered to operate as a unit and MUST be returned together. Carefully package the probe assembly in the carrying case. Use the original boxes and packing materials, if possible. If not, use the Parts List in Table 5—1 to order new boxes and foam packing from Holaday Industries, Inc.

NOTE

If your probe is calibrated in accordance with MIL-Std-45662A, it is greatly to your benefit to retain the original shipping box and packing materials. One of the criteria for certifying a calibration to MIL standards requires Holaday Industries to always ship equipment in the specified packaging. When a MIL Standard instrument is sent to Holaday in other packaging, we must replace it with the specified packaging materials for return shipment. YOU WILL BE BILLED FOR THE NEW PACKAGING.

If the probe is under warranty, refer to the Limited Warranty at the front of this manual for additional information about your return.

Periodic/Preventive Maintenance

The HI—4456 probe assembly (sensor and electronics

housing) require an annual calibration check to verify that they are performing within specifications. This calibration check may be performed at the factory by Holaday Service Personnel. Return your probe(s), using the original packing materials (if possible), to:

Holaday Industries Inc.
Attn. Service Department
14825 Martin Drive
Eden Prairie, MN USA 55344

Parts Information

Use the following tables for ordering replacement (Table 5—1) or optional (Table 5—2) parts for HI—4456 probes.

Table 5—1
Replacement Parts List

Part Description (Replacement Parts)	Part Number
Battery Pack, 3.6 VDC, Rechargeable	491038
Standard Fast Charger (115/230 Volt)	491198-36
Cable, Fiber Optic, Glass, 2 Meter	490994-02
Handle Assembly	491073
HI—4456 User's Manual	600075

Table 5–2
Optional Parts List

Part Description (Optional Parts)	Part Number
Probe Support, HI–4456	490984
Tripod, Dielectric, HI–4456	491000
Fiber Optic / RS232 Interface	HI–4413G

6.0 THEORY OF OPERATION

Introduction

This section discusses the theory of operation and the functions of the HI—4456 Isotropic Electric Field Probe. A high-level block diagram (Figure 6—1) is included to aid the discussion. The objective is to provide information that enhances user understanding of the design of this probe.

System Theory

The HI-4456 Broadband Isotropic Electric Field Probe uses three orthogonal thermal sensing elements. Each of the elements responds to the electric field component aligned with the particular element. The output of each element is proportional to the RMS value of the field component. The output of the three elements are summed as vector quantities and an output proportional to the resultant field generated.

A microprocessor is contained in the instrumentation housing located at the base of the probe shaft. The microprocessor generates an output corrected for variations in the sensor using lookup tables located in the processor memory. The resultant value is transmitted in an ASCII digital format through the optical cable to the readout. The probe's self-contained power supply employs a 3.6 VDC NiCd battery which provides up to 17 hours of continuous operation. Refer to Appendix B for details of the ASCII output formats.

For specialized applications, you may use a computer with an RS-232 serial port to communicate directly with the HI-4456 using the optional HI-4413G RS-232 interface.

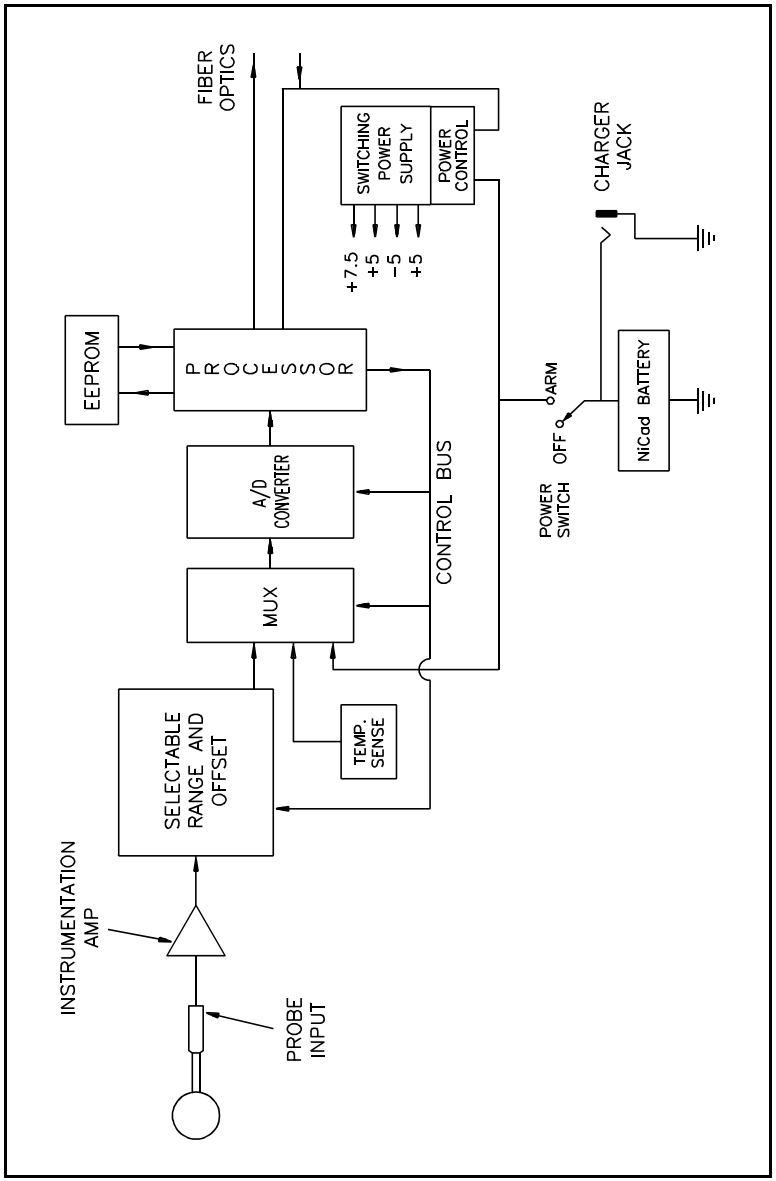

Figure 6–1
Probe Block Diagram

Probe Operation

Receiver commands to the probe consist of the following:

Send reading	Read battery voltage
Zero	Set sleep timer
Switch range	Read temperature
Enable axis	

The signal flow within the probe is shown in the block diagram.

To measure field strength, three mutually orthogonal dipole antennas (one per axis) are used to provide an isotropic response to the ambient field. The signal from each axis is fed to a Schottky diode detector operating in its Square-Law region. After filtering, the signals generated by each axis are added vectorially: the resultant is fed to the instrumentation amplifier, whose output feeds the selectable range/offset stage.

NOTE

The HI—4456 does not allow the option of measuring on an individual axis: all three axes are active at all times. Consequently, the axis keypads on the front panel of the HI—4416 System Readout have no effect when an HI—4456 is connected to it.

For each of the four ranges, the selectable range and offset stage provides a coarse analog zero for the measured signal. The output of the range/offset stage is fed to the A/D multiplexer, then to the analog-to-digital (A/D) converter itself.

After acquiring the composite three-axis signal, the microprocessor commands the A/D multiplexer to read the battery voltage and temperature sensing lines.

Data from the A/D converter is fed to the microprocessor, which transmits it to the receiver.
The EEPROM stores all calibration data for the probe.

Probe Power Supply
The HI–4456 probe is powered by a sealed rechargeable 3.6 VDC NiCd battery, which drives both the analog and digital power supplies: separate power sources provide isolation between the analog and digital circuitry. With the probe switch in the ARM position, battery voltage is applied to the power switch, which routes this voltage to the power supply, enabling the microprocessor. The power switch is controlled by a timer circuit. The timer monitors the fiber optic connector input line to determine whether the probe has received a command during a specified period (several seconds). If no command is received during this period, the timer signals the power switch to disable the power supply and the microprocessor. In essence, the probe goes dormant to conserve battery power: only the fiber optic input circuitry remains active in order to detect new commands. When the next command from the receiver reaches the probe, power is reapplied automatically and the processor is reactivated, "waking up" the probe.

NOTE
The probe uses volatile random access memory (RAM). If, for any reason, power to the probe is lost, the probe must be re-zeroed.

Zeroing
When the receiver sends a zero command, the probe must be in a zero field environment. This is because the zero command causes the multiplexer (via the processor) to perform a normal read cycle on the composite axis signal. This procedure is executed for all ranges. When

the processor receives all the zero-field values, it stores them in a special register; these values are subtracted from all subsequent measurements. Therefore, a probe which is zeroed while it is not in a zero field environment will give erroneous readings.

7.0 APPLICATION CONSIDERATIONS

Introduction
The following subsections contain information designed to help you maximize the effectiveness of the HI—4456.

Out-of-Band Considerations
Although the HI—4456 is nominally rated for operation from 300 MHz to 18 GHz, it may respond to signals both above and below these frequencies. Such responses must be taken into account when performing certain operations, such as zeroing.

On the lower end, the HI—4456 can exhibit significant response to frequencies below 300 MHz. Such out-of-band responses may pose a problem when zeroing the unit, since that operation assumes a zero field condition. At the upper end, similar problems may occur.

Resolution Limitations
Limitations in probe resolution may result in a non-zero reading when the receiver is zeroed. If this occurs, it does not necessarily mean either that there is a problem with the receiver or that your readings are inaccurate. Receiver linearity is specified as $\pm$ 0.5 dB full scale: in addition, the variance of the A/D converter is $\pm$ 2 least significant bits. When using the most sensitive range on a given probe, these specifications create the possibility that, under zero field conditions, the receiver may display a non-zero value.

Probe Support Structures
It is *very* important to keep conductive objects away from the HI—4456. Any such objects in the proximity of the probe may distort the near field and compromise measurement accuracy. If your application requires

measurements from a fixed position, always mount the probe on a non-metallic platform, using non-metallic screws.

APPENDIX A
ERROR CODES

Probe Error Output

If an error occurs, the probe will respond with one of the following strings. These strings begin with a colon and end with a carriage return.

E01 Communication error (e.g., overflow).

E02 Buffer full error. Too many characters contained between the Start Character/ Carriage Return sequence.

E03 The received command is not valid.

E04 The received parameter is not valid.

E05 Hardware error (e.g., EEPROM failure).

E06 Parity error.

APPENDIX B
HI—4456 OPERATING PROTOCOLS

Introduction

The information in this appendix assumes that you have purchased the optional HI—4413G Fiber Optic / RS232 Interface, and are capable of communicating directly with the HI—4456 probe via computer. No system readout is required when using this configuration.

Communication Protocol

Data Type:	RS-232 Serial
Data Mode:	Asynchronous
Word Length:	7 bit
Parity:	Odd
Stop Bits:	1
Data Rate:	9600 baud

Information Transfer Protocol

The HI—4456 operates as a Controller Mode device. This probe only responds to commands from another device; it transmits no data without first receiving instructions to do so.

Command Structure

A command to an HI—4456 probe consists of 1) a command letter, followed by 2) possible parameters, 3) terminated with a carriage return. When it completes the command, the probe responds with a string consisting of 1) a start character (":"), 2) the command letter, followed by 3) data, if required, and terminated with 4) a carriage

return. If the command does not require the probe to return any data, the probe simply responds with the command letter and a carriage return. If an error occurs, the probe responds with an error code, as detailed in Appendix A.

Commands

Command	Description
B	**Read battery voltage.**
Cx	**Set baud rate.** x = 1 sets rate to 2400 baud x = 2 sets rate to 9600 baud New baud rate does not take effect until the next power-up.
Dx	**Read probe data.** x = 1 enables short form output x = 2 enables long form output
Lx	**Load table data.** x = ASCII hex data
Rx	**Set range.** x = 1, 2, 3, 4 or N (next range)
Sx	**Sleep timer.** x = number of seconds to wait for a command before putting probe into the sleep mode.
Tx	**Read Temperature.** x = C or F
Ux	**Set unit type.** x = 1, 2, 3, or N (next unit) 1 = V/m 2 = mW/cm² 3 = [V/m]²

Vtx **Verify table data.** t = table (same table as for Lx command, above). x = number of bytes to send in one string.

Z **Zero.**

Null **Send the ASCII null character.** This is a special command that can be used as the initial command to the probe after it is powered up. The probe responds with “N”.

Probe Output

Command	HI—4456 Response

B **Bxx.xx,** where xx.xx is the battery voltage.

D1 **Dxx.xxuuu,** the short form output.

xx.xx is the reading. The position of the decimal point depends upon the range setting of the probe.

uuu = units
_V_ = V/m, mW2 = mW/cm², _V2 = [V/m]²
(underscore indicates a space character)

D2 **Dxx.xxuuurrrobaaat,** the long form output.

xx.xx = the reading, as described for D1.

uuu = units, as describe for D1.

rrr = recorder out value (A 3-digit ASCII number from 0 to 255).

o = over range indicator ("N" = ok, "O" = over range).

b = battery status ("N" = safe operating level, "W" = warning level, "F" = fail level).

aaa = axis enable ("E" = enabled).

t = terminating carriage return.

Rx **Rx,** where x is the range.
x = "" returns the range currently in use
x = 1, 2, 3, 4 enables the selected range
x = N sets the probe to the next (higher) range.

TF **Txxx,** where xxx is temperature in º Fahrenheit.

TC **Txxx,** where xxx is temperature in º Centigrade.

Vtx **Vxx[xx...],** where xx is table data in ASCII hex.

--NOTES--